



GUIDANCE, KNOWLEDGE, ADVOCACY
SERVING THE GLOBAL NATURAL GAS VEHICLE INDUSTRY

International NGV Technology Update

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Jan. 2014

NGVTF Brookhaven National Laboratory

NGV Global Activities

- Special Consultative Status with the United Nations
- Engaged in development of UN ECE regulations
- Representation on informal group on GFV/GRPE/WP29
- Engaged in development of ISO Standards
- Liaison status with several ISO and OIML committees
- Liaison with IGU Working Committee 5.3 (Utilization . Natural Gas Vehicles)
- Harmonization of standards big part of focus
- Information gathering and dissemination
- Weekly industry news via NGV Global News . www.ngvglobal.com.



Recent Technical Committee Activities

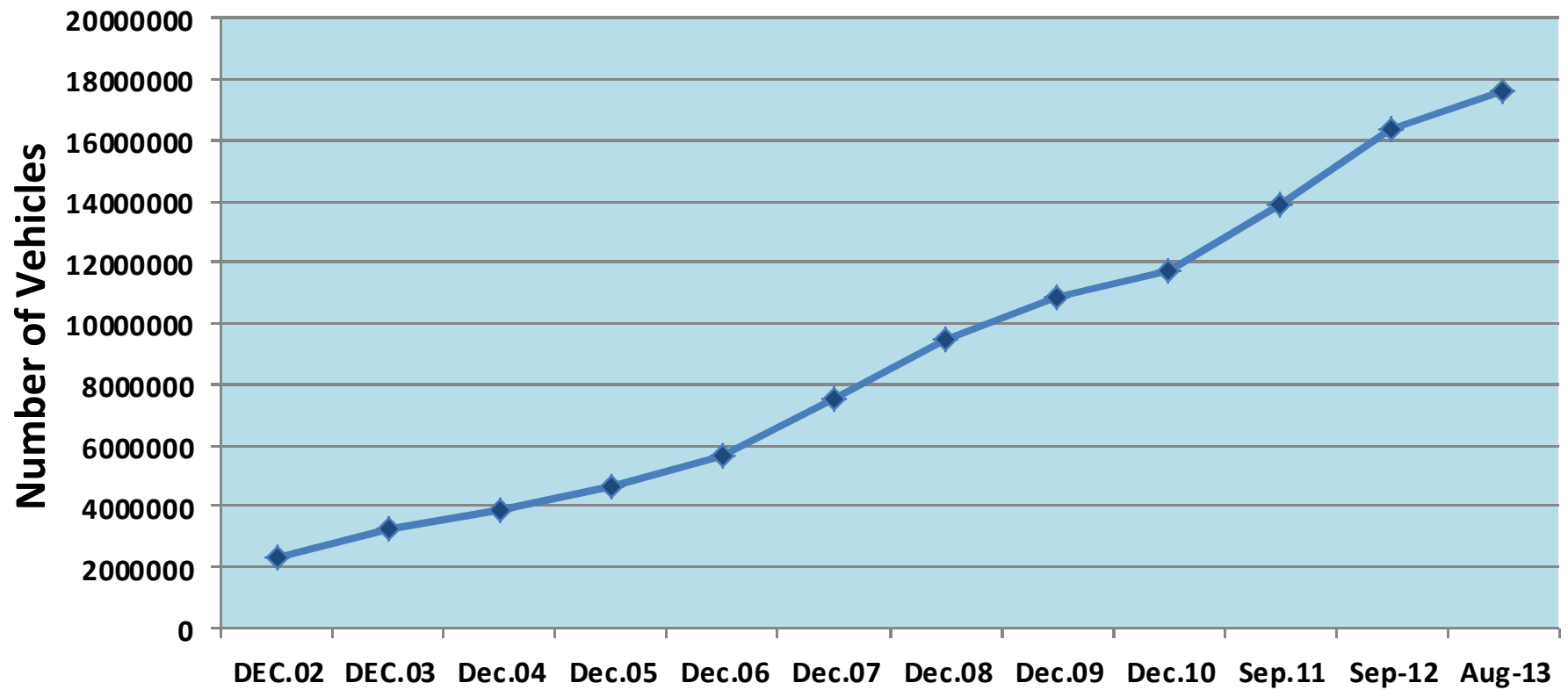
Meeting with cylinder manufacturers resulted in three issues being raised

- Cylinder mounting is a concern with limited instructions from manufacturers, and no regulation. NGVG considering preparing a best practice document for cylinder mounting
- Transparency in incident reporting. Disclosure different from country to country with reluctance to share information. No opportunity to learn what worked, what didn't work
- Valves and regulators. More incidents from components than vessels. Component manufacturers could also learn from shared information



NGV Population

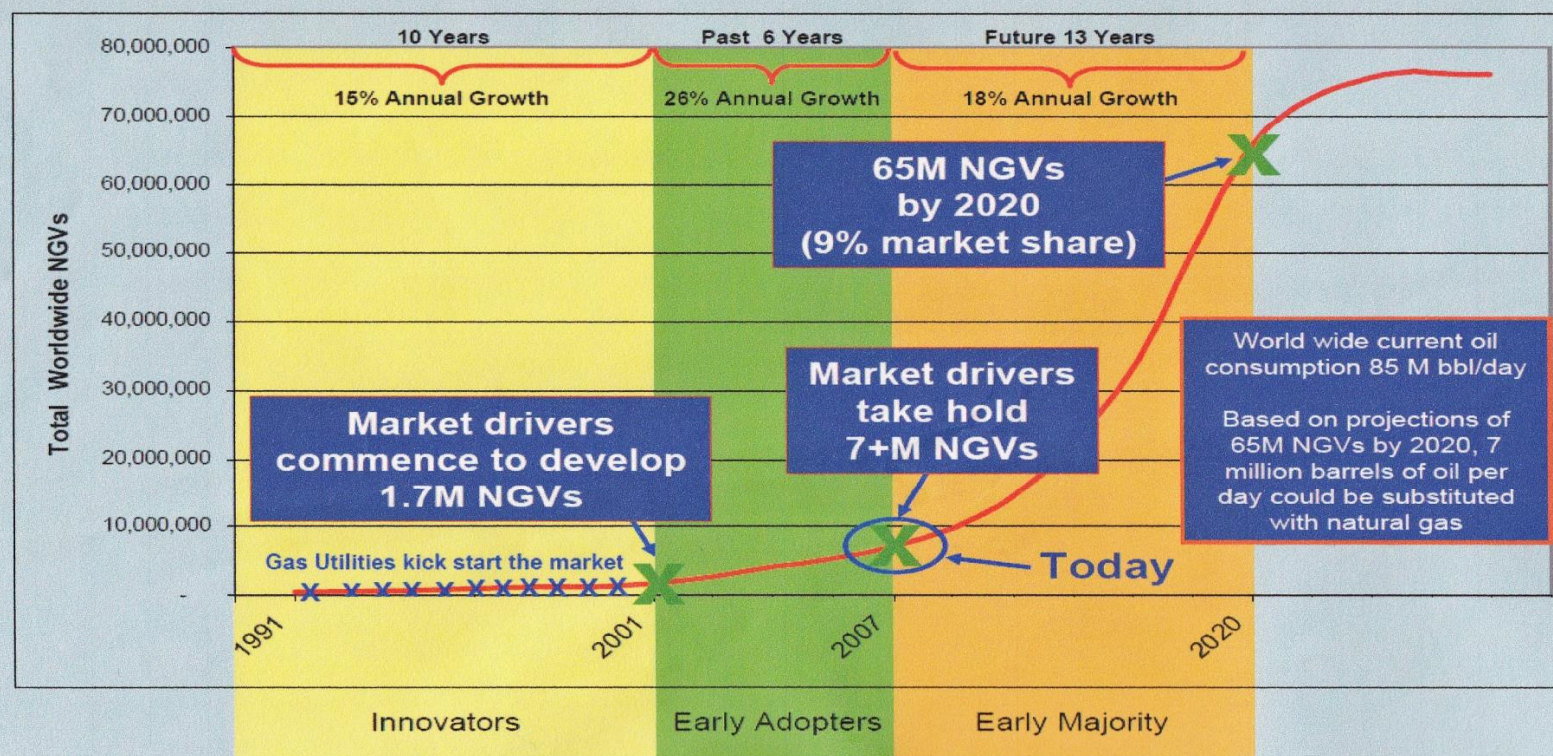
Number of NGVs Worldwide



NGV Population

Expected trend of the NGV market

NGV World Market "S Curve" 1991 to 2020



fonte: John Lyon, former President of IANGV - at NGV 2008 Rio De Janeiro



The Biggest NGV Markets in the World

IRAN

CNG Vehicles: ~3,300,000
~24% of national total market;
CNG ref. stations: 1,960

PAKISTAN

CNG Vehicles: ~ 3,100,000
~48% of national total market;
CNG ref. Stations: 3,330

ARGENTINA

CNG Vehicles: ~ 2,200,000
~20% of national total market;
CNG ref. stations: ~1,920

BRAZIL

CNG Vehicles: ~ 1,700,000
~5% of national total market;
CNG ref. stations: ~1,790

INDIA

CNG Vehicles: ~1,500,000
~4% of national total market;
CNG ref. stations: ~720

CHINA

CNG Vehicles: ~1,500,000
~2% of national total market;
CNG ref. stations: ~2,800

ITALY

CNG Vehicles: ~780,000
~2% of national total
market; CNG ref. stations:
>900



Canada

Development of Technical Training Courses

- 11 courses being developed from Fleet Operations to LNG bulk transfer.
- Interactive videos to classroom style learning
- CNGVA working with National Alternative Fuels Training Consortium (NAFTC) at U of West Virginia to develop many of these courses

Updating CSA B108 and B109

- Draft documents expected to be finalized in Q1 2014



Canada

Development of LNG refueling Guideline

- CSA Z276 Annex D expected to be finalized shortly
- Annex D addresses permanent LNG refueling stations
- Work also underway to look at specific needs of mobile refueling with reference to Annex D content
- CSA is working with industry/NRCAN to determine whether to have a standalone LNG refueling code that would incorporate both Annex D (permanent station) content as well as mobile station draft content



Canada

Emergency Response Requirements for Bulk Transfer of LNG/CNG

- Natural gas has historically been moved by pipeline, so bulk transfer by rail/truck new area for the NG industry
- Transport Canada requires bulk transfer to have an emergency response assistance plan providing details of response time, trained personnel as well as spare equipment.
- Possibly have the propane industry expand its emergency services coverage to LNG/CNG



Canada

GE Canada making progress with LNG rail applications

Transport Canada more open to this than US

Only 7 major rail companies. One converts, all convert

Long term gas pricing helps.

Rail Transformation



Europe

Ten-T Project

- In May 2013, landmark agreement signed by the Commission and Parliament to transform the existing patchwork of road, rail, canals into a new trans-European transport network across 28 member states
- 9 core network corridors scheduled for 2030, which will include natural gas infrastructure with 150 km between CNG stations and 400 km between LNG stations
- Encouraging the use of LNG as a marine fuel is also a priority with LNG bunkering studies being funded.



Europe

LNG will play a significant Role

Norwegian NOX fund used to assist shipping

12 LNG ships in 2012,
12 more in 2013

30 LNG carriers deliver 200
LNG shipments/yr in Europe

By 2016 25% of motive
power provided by LNG



Europe - Finland

Viking Line operates the LNG Ferry Viking Grace from Turku Finland to Stockholm, equipped with 4 Wartsila 7600 kW dual fuel engines. The ferry can be refueled With LNG in 40 minutes, which is the same time as conventional fuels.



Source: NGVA Europe 2013

Europe - Finland

Wartsila new marine 2-stroke dual fuel engine

Lower cost LNG and gas handling system operating at low pressures below 10 bar

Nox abatement systems not required

At low loads no need to switch to diesel fuel, so stable operation on gas across the entire load range

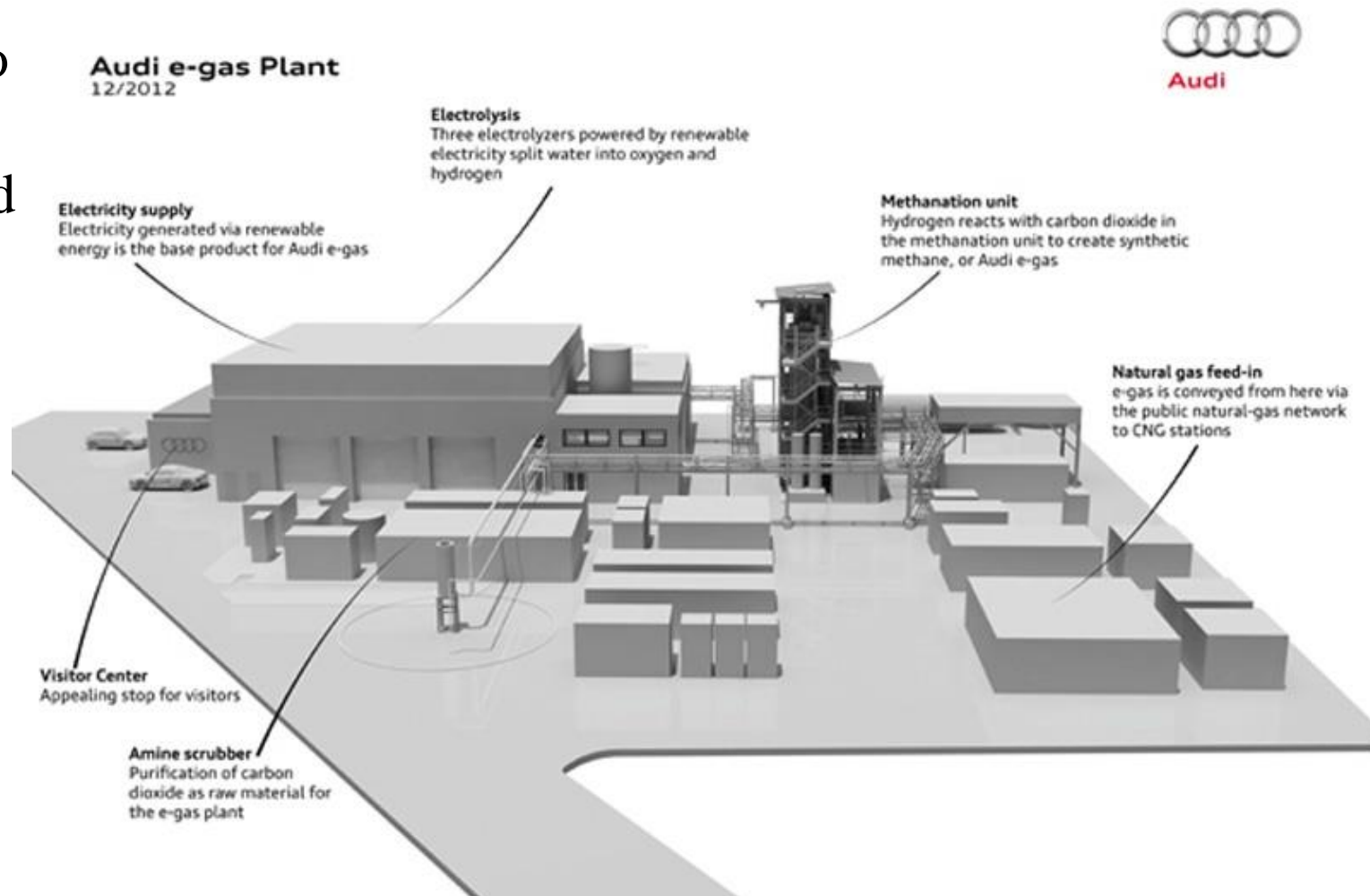
Pilot fuel only 1% of total fuel



Europe - Germany

Garbage burned to produce CO₂ which is combined with H₂ to produce CH₄

Land use is 20 times less than conventional biomethane production



Europe - Italy

Natural gas as fuel: a new opportunity for the automotive sector: Italy

In Italy new OEM NGV sales and CNG vehicle conversions in the first half of 2012 are very positive despite the elimination of former financial incentives. A growth of 36% on sales is confirmed with 43,300 new NGVs (OEM + conversions as of June 2012). The share of new OEM NGV on the total sales of new vehicles has increased from 2.21% in 2011 to 3.60% in 2012, with a 4.52% peak in April.[source: Centro Studi Promotor]

year	new OEM LD Vehicles	New OEM NGV LD	NGV share of new OEM
2006	2,657,600	29,180	1.10%
2007	2,843,495	65,302	2.30%
2008	2,493,743	87,007	3.22%
2009	2,407,152	139,991	5.82%
2010	2,196,298	84,780	3.86%
2011	1,977,059	43,779	2.21%
2012 as of September	1,076,168	43,825	3.60%

NOTES:

Source of data: Ministry of Transport

in 2008 and 2009 special incentives were offered by Government for purchase of new OEM NGV

Source: Mariarosa Baroni NGV Italia



Europe - Italy FPT

3 L F1C CNG



Euro V / VI: 100 kW / 350 Nm
Euro VI ECU, TWC upgrade

5.9 L NEF 6CNG



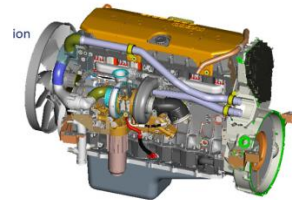
Euro V: 147 kW/ 650 Nm
Euro VI: 150 kW/ 750 Nm
(Production scheduled in Q4 2014)
ECU/TWC upgrade, ion sensing coils

7.8 L Cursor 8 CNG

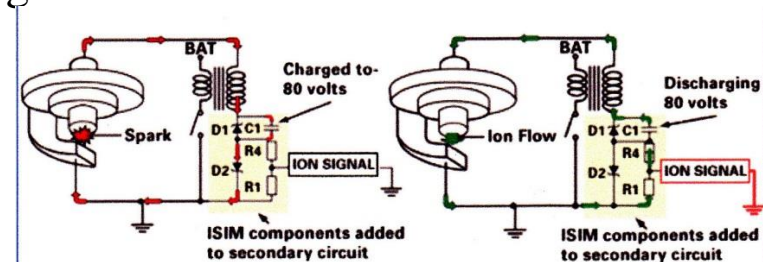
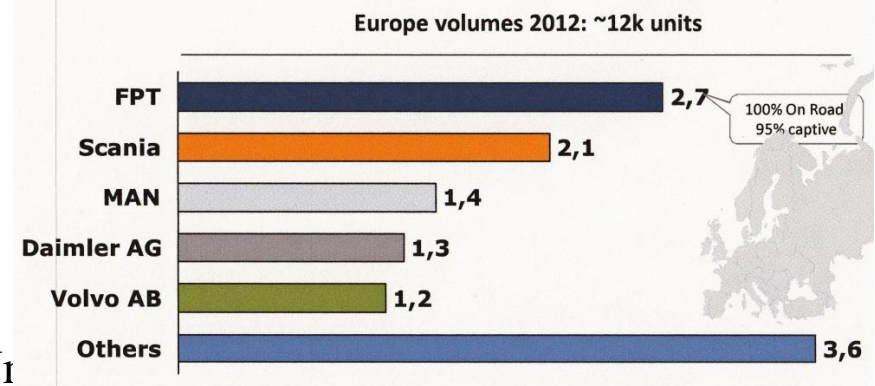


Euro V / VI: 243 kW/ 1300 Nm
Euro VI ECU/ ion sensing coils

12.9 L Cursor 13



Euro VI: 338 kW/ 2000 Nm
(Production scheduled in Q1 2015)



Typical ion sensing system



Europe - Italy Dual Fuel Systems



Selection of vehicles in the field

1.9l

78/90 kW

Euro 4



2.5l

75/116 kW

Euro 4



Various LCV

2.3l to 3.0l

Euro IV



2.8l

122 kW

Euro III



7.6l

395 kW

Euro II



3.9l / 5.8l

125/176 kW

Euro III



12.5l

355 kW

Euro III



7.8 l

259 kW

Euro III



12.1l

338 kW

Euro III



12.5l

373 kW

EPA OUL



Europe - Dual Fuel Systems

- “ Working Group session on Dual Fuel for several years (GFV activity)
- É Dual Fuel OEM systems officially introduced from Euro VI for HD
- É Dual Fuel Retrofit systems regulation under discussion
- É Emissions point of view:
 - DF is classified as CI engine, except for MHC, which are compared to SI Gas engines

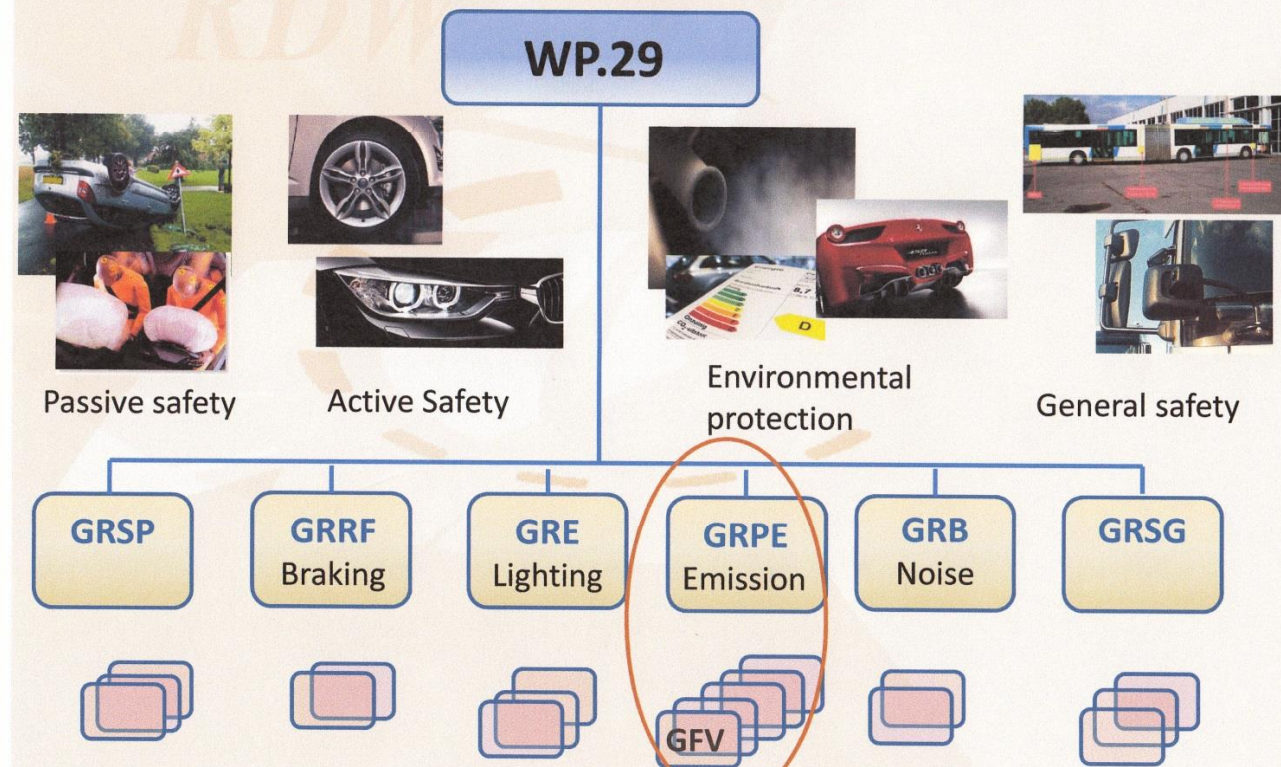


Europe - Informal Group on Gaseous Fuel Vehicles



Vehicle Authority – The Netherlands

WP.29 “World Forum for Harmonization of Vehicle Regulations”



André Rijnders Poli-technic workshop
26-27 March 2013 Brussels



Europe – GFV Items

Task Force on Liquefied Natural Gas (LNG)

After two years of work, amendments to ECE R110 have been adopted which will allow LNG vehicles to be fully certified in 50 countries that incorporate UN regulations in their national regulations.

Amendments to R115

For Bi-fuel vehicles with petrol direct injection engines, it is permissible to use petrol only or simultaneously with LPG during the entire test cycle provided that the energy consumption of gas is higher than 80 per cent of the total amount of energy consumed during the test.

Improvements for Euro 6 LD

Special GFV item

a European proposal for amendments to M1 and N1 vehicles emission regulation (Euro 5/6) concerning THC / CH₄ (methane) still in progress.



Europe – GFV Items

Task Force on Heavy Duty Dual Fuel (HDDF) Systems

Regulation 582/2011 for new Euro VI HDDF engines. 3rd round of comitology adopted July 2013 still in progress. Publication Jan 2014

HDDF retrofit Type B regulations now in progress. ECE R49. Issues:

- “ Euro IV and V engines only
- “ Even if the parent engine is non compliant with the emissions limits, the HDDF retrofit, the parent engine equipped with the HDDF system must meet the original emission values.
- “ The converter takes full responsibility for the engine in-service conformity

WP15 Carriage of dangerous goods (ADR)

Fuel leakage from ADR regulated trucks must go to the ground.



Europe – Russia

NEW 12 L CNG ENGINE COMING TO MARKET

Russian truck manufacturer KAMAZ and Swiss machinery and equipment manufacturer are setting up a production operation to manufacture 6 cylinder 12 L engines.

Initially Euro V diesel and CNG engines will lead to Euro VI engines.



Europe – Russia Rail Applications

- World record (Russia)
 - ▣ Largest load by a single locomotive
 - ▣ 8300 KW,
 - ▣ 17 tonne LNG fuel tank
 - ▣ 16,000 tonnes, 170 rail cars
- Potential fuel savings of millions of dollars for operators

LNG-Powered GT1 Locomotive Sets New World Record

September 14, 2011 – 9:15 am | Russia, Moscow



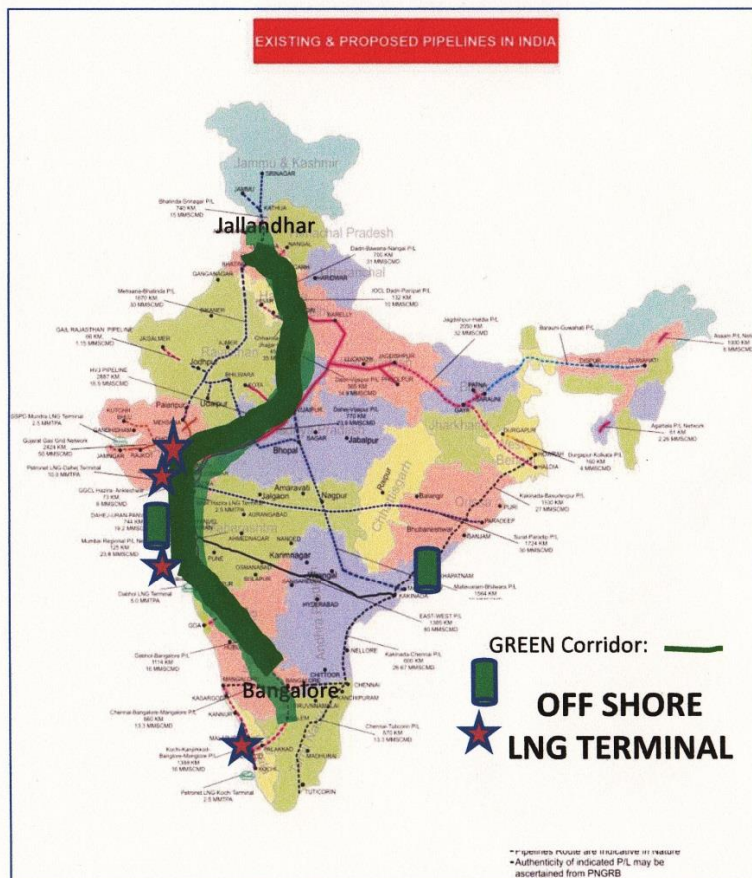
LNG-powered GT1 sets new world record.

The Russian-developed GT1-001 gas turbine-electric locomotive has successfully undergone further field tests in Moscow, in readiness for deployment on non-electrified freight-intensive areas of the railways. Hauling 16,000 tonnes in 170 rail cars, a new world record for a single prime mover with an internal combustion engine, the 300 tonne two-section GT1 combines a turbine and power unit with a separate section containing the 17 tonne liquefied natural gas (LNG) fuel tank. The engine can develop 8300 kW of power and when fully fuelled can drive the train 750 kms with a top speed of 100 km per hour.



India

Green Corridor : Jalandhar to Bangalore



- Gas sources : Bombay High, South Bassien, D-6 and 3 operational LNG Terminals
- Jalandhar to Bangalore Gas Pipeline segments are already operational
- CNG stations at every 200 km
- Benefits :
 - Energy Security
 - Sustainable and environment friendly
 - Reduction of Govt Subsidy burden in POL products

India Issues with Infrastructure Expansion

- High population density
- Small size of stations and demand pattern creates long queues of vehicles
- Unavailability of space for capacity enhancement



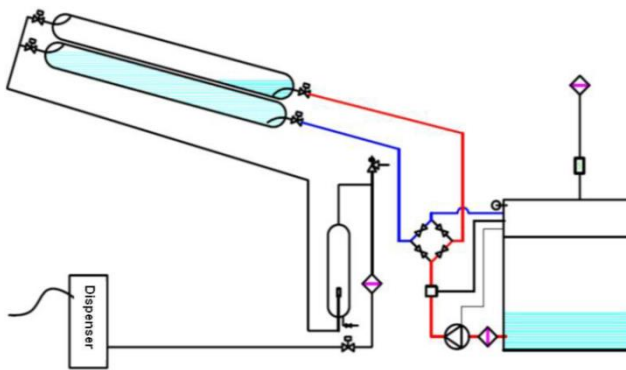
India Way Forward

- Roof mounted compressors
- Government allocation of land
- Skid mounted time fill stations



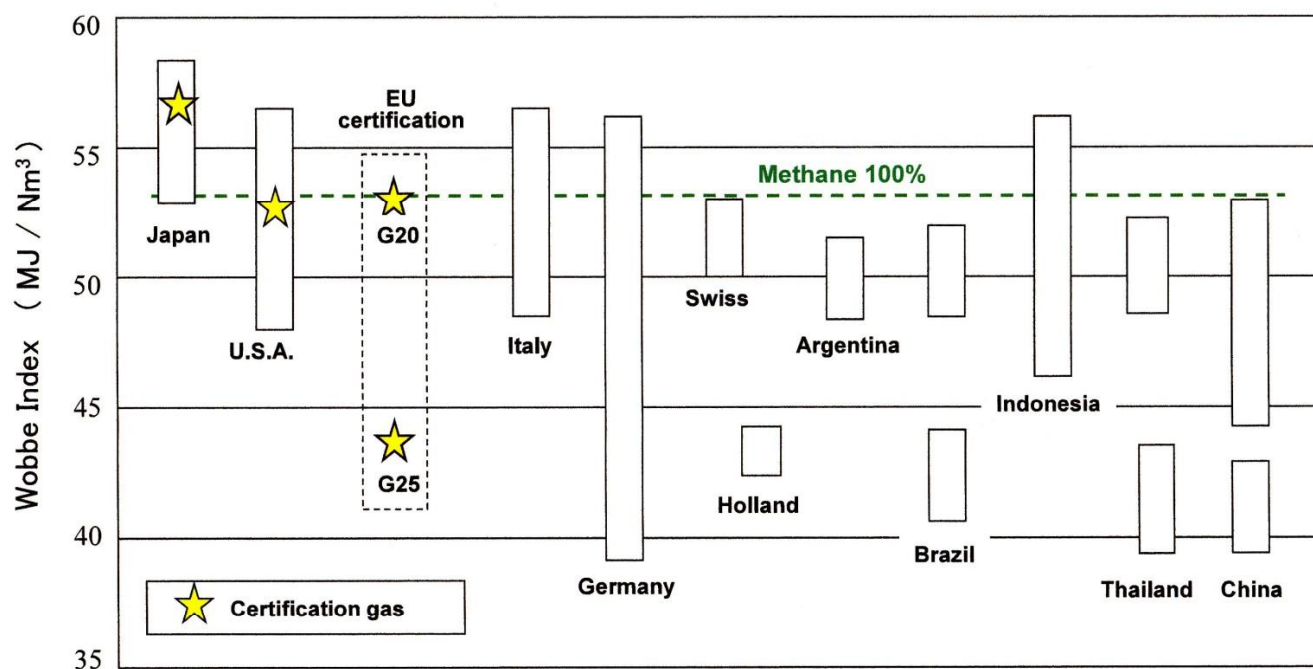
China 1.5 million NGVs 60 manufacturers

CIMC ENRIC Hydraulic Daughter Stations



Japan – Honda R&D Proposal for WW CNG Fuel Spec.

Comparison of Wobbe Index in Various Countries



$$WI = H / \sqrt{S}$$

H: High calorific value (MJ/Nm³)

S: Specific gravity (Air=1)

Calorific values and composition of natural gas vary among countries or regions.
Europe, US and Japan have their own CNG certification fuel specifications.

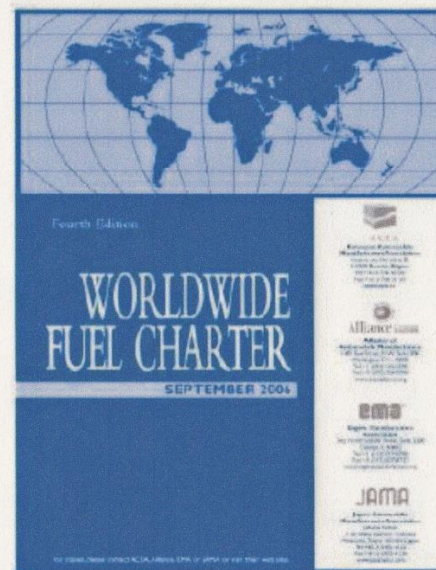
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Japan – Honda R&D Proposal for WW CNG Fuel Spec.

What is World Wide Fuel Charter(WWFC) ?



- The Automotive industry's guiding document towards improved and harmonized market fuel quality (gasoline and diesel fuel)
- Latest version from Sept 2006, **next revision in progress, target for finalization: by mid 2012**
- **Gasoline and diesel fuel quality in four quality levels (Category 1,2,3,4), to match emissions requirements (up to Euro 5/US10 or equivalent)**
- WWFC can be downloaded from www.acea.be
www.autoalliance.org



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ANGVA 2013 Conference & Exhibition
2013 November 28



Japan – Honda R&D Proposal for WW CNG Fuel Spec.

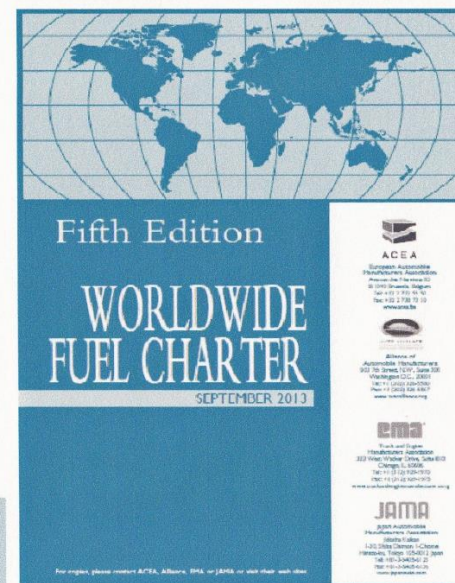
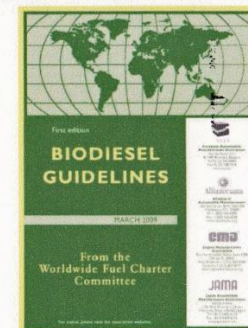
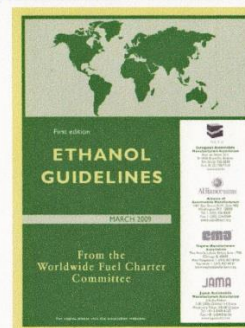
History of WWFC and Concept of the 5th Edition

Recent Publications

- WWFC 4th Edition (2006)
- WWFC Biofuels Guidelines (2009)
Ethanol / Biodiesel
- WWFC 5th Edition (2013.10)

Concept of the 5th Edition

- Creation of “Category 5” as “Top of the technical definition”, and extended acceptance of biofuels as blending components
- Category 5: fuels for markets with highly advanced emission control and fuel efficiency
- Category 5 gasoline specification
 - **Min. 95 RON requirement** for improved thermal efficiency and fuel economy
 - **Max. 10% bio-ethanol blend allowed**
- Category 5 diesel fuel specification
 - **FAME not allowed**, but max 5% allowed in Cat. 4
 - **Bio-components such as HVO and BTL are recommended** provide that finished fuel meets required specifications.



Japan – Honda R&D Proposal for WW CNG Fuel Spec.

Proposal for CNG Guideline for Vehicles (*under discussion*)



Gross WI (MJ/m ³)	High calorie: >48, Mid. calorie: 40–48 Margin: ± 3 MJ/m ³
Sulfur	Same level as for gasoline, varying according to emission level
HC	No specific standard for each HC species
Liquid HC	1% max. at pressure (5.3–8.3Mpa) and lowest temperature
Methane Number*	High: min. >80, Mid: min. 70–80, Low: min. 65–70
Water (Dew point)	Below ambient temp. of -5°C at working pressure which is either 20Mpa or 25Mpa in most countries
Lubricant contamination	25mg/m ³ max. at working pressure of 20Mpa
O ₂ , H ₂ , CO	O ₂ : 1mol % max., H ₂ : 0.1 mol % max., CO: 0.1 mol % max.
CO ₂	5 mol % max.
Metal, particulate contaminants	Non-detectable Si, H ₂ S : non-detectable

*Methane Number : Calculation method need to be discussed further.

JAMA is in cooperation with ACEA and Alliance(US) to determine specifications for WWFC–CNG.

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Message from TÜV on Safety

1. Accidents may happen but the experience world wide shows:

Natural Gas Vehicles are as safe,
And even safer than any gasoline-powered vehicle.



IMPACT RUPTURED GASOLINE TANK,
CAUSING FIRE



NO LEAK OR RUPTURE OF THE NATURAL
GAS FUEL TANK OR SYSTEM



TWO CNG BUSES COLLIDE

Accidents may happen



CNG buses are now so common that they are hitting each other?



Final Message

NGVs worldwide are alive and well

Technology is advancing,

Vehicle populations are growing rapidly

**Off-road marine and rail markets offer
significant new demand for fuel and technologies**

Thank you for your attention

